PENOBSCOT BRIDGE

HAER No. ME-52

Spanning the Penobscot River along
Route 15, approximately .5 miles
northeast of the junction of Routes 15 & #1A.
Bangor
Penobscot County
Maine

HAER
ME
10-BANG,
1-

PHOTOGRAPHS

WRITTEN HISTORICAL AND DESCRIPTIVE DATA

HISTORIC AMERICAN ENGINEERING RECORD
National Park Service
Northeast Region
Philadelphia Support Office
U.S. Custom House
200 Chestnut Street
Philadelphia, P.A. 19106

HAER
ME
10-BANG
1-

HISTORIC AMERICAN ENGINEERING RECORD

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Bangor
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UTM: 19.518689.4960460
QUAD: Bangor, Maine 1:24,000

Date of Construction: 1902

Engineer: American Bridge Company, Chicago ,IL.
Construction engineer - unknown
Subsequent work engineers - unknown

Spans #2 & #3 (1911) - Boston Bridge Works
Boston, MA
Construction engineer - unknown

Present Owner: Dept. of Transportation
State of Maine

Present Use: Two-lane vehicular traffic across the Penobscot River, between Bangor and Brewer

Significance: This bridge is the last remaining Baltimore (Petit) through-truss bridge in the state. The current structure represents three different phases of construction: Phase 1 - the center span was erected in 1902 by the American Bridge Co. to replace the center wooden covered section lost in spring flooding; Phase 2 - the spans at either end of the center span were added in 1911 by the Boston Bridge Works Co. to replace the remaining wooden covered bridge section; and Phase 3 - three pony trusses (no longer extant) were erected at the west end of the existing structure, replaced with a steel girder truss section in 1934 and 1963.

Project Info.: The Penobscot Bridge, known locally as the Bangor-Brewer bridge, is scheduled for replacement. While it remains in operation, many steel structural joints, as well as the piers, show signs of severe wear, and its rated tonnage has been lowered to 3 tons from 15 tons (est.).

This documentation project was performed in cooperation with the Maine Historic Preservation Commission under contract #94P-394076. The written documentation was performed by Erik W. Carson; the photographic documentation was performed by Brian Vandenbrink.

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Location History -

The first bridge to cross the Penobscot River at this site was erected in 1832 by Isaac Damon in 1832. Damon was a close associate of Ithiel Town, and used Town's lattice-bridge plan. It is the earliest of its kind in the state . Using a lithograph produced by William S. Pendleton, the bridge is shown as a white, pitched roof structure, resting on a large stone pier at the Bangor shore. Town's lattice system prevented the use of numerous windows, thus presumably creating a long dark tunnel. In 1846, during the ice breakup and subsequent "freshet", this bridge was washed away; it was rebuilt in 1847, using the Howe truss system.[1]

This latter replacement is described by Deborah Thompson in her history of Bangor as. . .

> . . . more substantial than the first bridge and in a better style. This pitched-roof bridge had paired trusses on either side of its pylon-shaped piers and a close progression of small square windows.[2]

The location of this bridge, however, gives a good clue to the dangers of building bridges across rivers, especially in Maine, for on March 20, 1902 spring "freshets" swept away not only the center section of this bridge, but also the Maine Central Railroad bridge nearby.

At the same time, a movement begun as early as 1895 was building momentum to make the bridge a "free" bridge, that is, without tolls. Thus, by 1902, the mayors of both cities having petitioned the Chief Justice of the State Supreme Court to appoint appraisers to determine the company's net worth and holding, the Bangor Bridge Company was created through an act of the legislature on March 31, 1901.[3]

In the April 15, 1902 edition of the Bangor Daily News, it was announced by Mayor Engel of Bangor and Mayor Higgins of Brewer, that the bid for the construction of the steel span bridge across the Penobscot was awarded to the American Bridge Company, of Chicago, Illinois. Their lowest bid was for $24,500, of which $21,000 was for the steel work, and $3,500 for the wooden falsework. The terms of the contract were quite clear: the span had to be completed for travel on or before October 1st of that same year, and that the falsework would be completed in twenty days from the signing of the contract.

In an interesting series of articles carried in the Bangor Daily News, one can trace the progress of the replacement of both the Penobscot Bridge and the nearby railroad bridge, both soon to consist of steel through-truss structures. The work described below was for the construction of a temporary footbridge to carry pedestrian traffic between the two cities. Nevertheless, the methodology of oonstructing a truss bridge is the same, and this incredibly detailed account can be used for the documentation purposes here:

> At 3.27 o'olock [sic] on Friday afternoon the first of the floor timbers was slid out to its place a minute later one of the workmen, seated in his "bo's'n's chair," was allowed to slide slowly down the river cable to the oentre, where the timber was, and he began the work of fastening it to the cable. The work was slow and some time was consumed in seouring it. When the lower side had been securely fastened a second man dropped into his place in the "bo's'n chair" and was lowered down to the centre of the up-river cable, where he proceeded to make that the end of the timber fast to the cable.
>
> This morning four men will be set to work in the "bo's'n Chairs" and the floor beams will be sent out from both the Bangor and Brewer shore, so that the work of stringing them in place will proceed very rapidly and will, also, be from the oentre shoreward on both sides.
>
> These floor beams are to be placed five feet apart. They are secured to the steel suspenders before being sent out to their place in the bridge, the top of the suspender is loosely clamped about the cable so that it can slide down the incline. When all is ready it is started and goes slowly down the two big steel ropes until stopped by the men who are to secure it in place. As soon as a beam is secured another is sent out so that the work goes along rapidly.
>
> BEAMS IN PLACE TODAY
>
> It was stated on Friday afternoon by the men in charge of the work that all the floor beams would be in place and the suspenders securely clamped by tonight. When this is done the side trusses will be plaoed in position, which is not a very difficult job. These trusses are all put together at the present time in the Bangor side of the toll bridge and are ready to be slid out into position as soon as the floor timbers are ready to receive them.
>
> Two wire ropes will be used to swing these trusses out into place. By means of the ropes they will be hauled from the Bangor side to the Brewer side, dropped into place, fastened and the work of laying the floor of the bridge will be begun.[4]

At the same time, the necessary cribwork was erected to support the final bridge trusses, which were typically shipped in pieces, and erected just off-site, with the individual trusses slid into place as described above. In another account of the erection of the two bridges, as reported in the News, an excellent drawing using a photograph taken from inside the remaining wooden covered bridge, shows the assembling of the steel framing for the footbridge.[5] In short, two bridges were replaced at the same time. The above description oulines the railroad bridge replacement, but given the similar construction, can be used to describe the process for the auto/pedestrian bridge as well.

Just fifteen days after the work began, the suspension bridge was opened for pedestrian traffic, to carry some 4,000 people across the river the first day. The rigging crew was led by J. F. Angley, the carpenters by Dayton G. Tibbetts, and the bridge erection by Edward Knowlton of the Bangor Bridge Company. With the successful completion of the temporary span, the work on the major replacement could begin, and by October, the new steel span was in place.

Bridge Design History -

Truss bridges were virtually unknown until the 16th century, when da Vinci and Palladio invented and built wood truss frames for bridges, designs which differ little from those used during the time of the erection of the Penobscot River Bridge.[6] Developed c. 1570, Palladio's king-post truss was perhaps the first. The use of the truss, based on the inherent strength of the isosceles triangle, given the truss advantages over the bent, or arched bridge. It was stronger, given the size of the members, and could be erected partly off-site, then maneuvered into place. It wasn't until 1798, however, that Theodore Burr rediscovered Palladio's designs, and used them in his bridge designs. Burr's truss consisted of a top and bottom chord, slender hip vertical, and larger diagonals. This type of bridge was found to be unstable under moving loads, however, and was stiffened though the use of the arch, thus more resembling an arched bridge, given the rise at the center.[7]

Briefly, truss bridges consist of either "deck" bridges or "through" bridges. The former consist of a floor system which connects the trusses at their tops, and traffic moves along on the deck, hence the name. The latter consists of a floor system which connects to the bottoms of the trusses, and traffic moves through the space between the trusses.[8] The subject bridge is an example of this latter type.

The first iron truss railroad bridge, erected in 1823 on the Stockton and Darlington railroad crossing the Gaundless River near West Auckland, England, had four spans. The spans were only 12'-6" long, supported on cast iron bents. By 1830, the principle of the double cross-bracing in the truss panel was used, and with that came the Howe, Pratt, Whipple, Warren and other truss designs in quick succession. In 1833, the first American patent for an iron truss bridge was issued to August Canfield, but the first iron girder bridge in America was erected at Frankford, N.Y., spanning the Erie Canal by 77 feet. The 1840 design by Earl Trumbell, of Little Falls, N.Y., consisted of cast iron girders strengthened by wrought iron bars, thus combining the strength of a truss bridge with that of a suspension bridge.[9]

The "Howe" truss , patented in 1840 by William Howe, was used only until about 1870. His first bridge was completed in 1840, and his second consisted of a railroad bridge over the Connecticut River at Springfield, with seven spans totaling 180 feet. The latter was replaced by another Howe bridge thirteen years later, which in turn was replaced in 1874 with a double track wrought iron bridge.[10]

According to some authorities, Howe's truss was the first in which metal was employed, albeit still largely constructed of timbers. This truss was unique in that it relied on the compressive strength of wood, and its low tensile strength substituted the tensile strength of iron. The wood diagonal members were in compression, whereas the vertical members, in tension, consisted of iron rods. The lower chord was in tension as well, and after 1850 this was typically made of iron. The upper chord, exposed only to compressive strains, continued to be built of wood.[11]

The "Pratt" truss, designed by Caleb and Thomas Pratt in 1844, was used until approximately 1905.[12] At first, the Pratt truss was simply seen as an improvement on the Howe truss; that is, the same chord arrangement was used, but with a different web organization. The vertical members were in compression, the diagonals in tension, and for the first twelve years the vertical web members were made of wood, and the diagonal web members made of iron. After 1850, however, the Pratt truss was construction entirely of metal, first of iron and later of steel, and came to be a standard-bearer. While rarely shorter than 100 feet, it was also rarely longer than 200 feet.[13] In 1852, the all iron Pratt truss was introduced.

In 1847, Squire Whipple patented the "Whipple" truss , which served to improve upon the "Pratt" truss. The latter consisted of a frame in which the upper chord and the vertical web members were in compression, the lower chord and the diagonals in tension.[14] Whipple kept this organization, but carried each diagonal across two of the panels framed by vertical units. Built completely of wrought iron, the Whipple truss was able to be erected in spans longer than 200 feet. This truss type became the "Whipple-Murphy" truss after design changed in 1863 by J. W. Murphy, when the cast-iron struts were replaced by wrought iron, with special cast-iron seatings at eaoh joint, for a bridge designed to cross the Lehigh River at Mauch Chunk, Pennsylvania.[15]

Further modifications created the "Linville" truss when it was constructed entirely of wrought iron. In 163-4, J. H. Linville, a chief engineer for the Pennsylvania Central Railroad Company, built a 320 foot long truss at Steubenville, incorporating the 1861 patent he had received for using forged eye-bars as tension members in a bridge over the Schuykill River for the Pennsylvania Railroad.

The "Bollman" truss was perhaps the next logical development, derived from the Whipple truss. It may be better known as the first truss intended to be built exclusively of metal. Introduced in 1850 by Wendell Bollman, and used until approximately 1875, it differed from the above through its used of diagonals in tension, half of whioh originated at either end of the truss, and off of which carried across any number of panels. In a truss of this type, the lower chord was reduced to either add stiffening or was omitted altogether. The upper chord however, remained, under compression loads, and built as an arc, flattened with loading. This downward thrust was carried, in turn, from each panel point through the vertical members (in compression) to the diagonal members (in tension); and through the diagonals in turn the entire strain is carried to supports at either end of the truss. All of the tension members were made of wrought iron, and as a rule, the compression members were made of cast iron.[16]

The "Warren" truss , patented in England in 1838, was developed for use in America around the time of the Civil War. It originally consisted of upper and lower chords, with an additional element of a web composed entirely of diagonals, arranged in a series of "V's". It resembled the Pratt truss, only without half the diagonals and all the vertical. In action, however, it behaved much differently, for under a moving load, every diagonal worked alternately to accept the load in compression and tension. As originally constructed, the Warren truss members were connect by pin, first wrought iron which ran through holes and eyelets, and later with rivets. The latter improvement served to make the truss rigid, with vertical members added later to the web, thus taking up some of the tension. This simple but uniquely effective manner of taking up the load (that is, the diagonal members, thus taking up the two strains alternatively) were able to take the strain of compression without bending. For longer spans, additional vertical tensioning rods were added, creating a "sub-divided" panel truss.[17]

Finally, the Baltimore truss was patented in 1877 by the Pennsylvania Railroad Co. The Baltimore tress consisted of two classes, those in which the half-diagonals (or sub-diagonals) are in compression, and those in which the sub-diagonals are in tension. The latter class is the one most typically constructed, since it is more economical given that while many of its members are in tension, they are cheaper and easier to build than if those members were in compression.

In theory, one third of the deal panel load is applied at the upper ends of the long verticals and half-verticals (or sub-verticals), and are stressed by dead load only. The top chords, end-post verticals, and center verticals take compression, the rest taking tension. The diagonals typically are at a 45 degree angle with the verticals.[18]

With the coming of the Bessemer process of steel production in 1855, and the Siemens-Martin process soon afterward, iron began to fall out of favor in bridge construction, and by 1895 wrought iron had ceased to be used for either rolled or structural bridge parts.[19] The development of steel for bridge construction began perhaps with William Ellyott and Matthias Meysey in 1614 in England, when they were granted a patent to convert iron into steel via a "reverberatory" furnace, so-called because its construction forced flames and flue gases directly on the iron, and the top of the furnace was shaped to reflect the heat back towards the iron. The only problem was this process' dependence on charcoal, a limited item.[20]

In 1740, Benjamin Huntsman produced molten steel which could be poured like cast iron, in Sheffield, England. By controlling the carbon content, he was able to more simply produce cheaper steel. Still, however, he was unable to reduce the carbon content to produce a steel which could be welded.[21] Despite this and other improvements in the industry, steel production could not compete with iron. It wasn't until William Kelley, working in Eddyville, Kentucky, noticed that when molten pig-iron was not covered with charcoal, it became hotter when air was blown on it. He correctly assumed that the carbon in the iron was acting to fuel these hotter temperatures. In 1851, he built the first of seven converters to produce steel. His application for a patent was questioned given Bessemer's earlier patent. Able to convince patent officials of his earlier work, he was granted a patent on June 23, 1857. The financial strain was too much, however, for he went bankrupt within the year.[22]

Henry Bessemer, on the other hand, was far more successful as the process' namesake. The process proved difficult, however, as Bessemer's work had utilized pig-iron made from Cumberland (England) ore, which was totally free of phosphorus. The converter he used for burning off the excess carbon had an acid lining, which proved unsuitable for use with ores containing acid impurities.[23] It was not until Thomas lined both the converter and the furnace with fireproof material in 1878 that the problem was solved. Thus, there were two kinds of steel produced, depending upon their hardness. "Mild steel" became the preferred building material, given its greater structural reliability, uniformity, and resilience. Bessemer's acid steel was too hard and irregular of texture to be easily worked. It was not until the latter part of the 19th century that the process, and the material, came to be trusted and used exclusively.

Members of a truss consist of a top and bottom chord, end-posts, and web members. The web members are further differentiated into hip-vertical, intermediate posts, and diagonals In addition, in all through-truss bridges (except pony trusses), the chords which are not connected by the floor system are connected by a horizontal truss system called lateral bracing. In all bridges, the chords which are connected by the floor system are connected by a horizontal truss system, also called lateral bracing. These systems are further divided into top lateral systems (as connecting the top chords), and bottom lateral systems, (as connecting the bottom chords).[24]

The end-posts of the pair of trusses are connected by a system of braces, in order to maintain the rectangular cross-section of the bridge. This bracing is called portal bracing. Sway bracing and knee-braces serve the same purpose, and consist of either small struts or systems of cross-bracing placed at the intermediate posts (the former knee-braces and the latter sway bracing).[25]

The Penobscot Bridge also had pony trusses at one end. A pony truss bridge exists when the height of the trusses of a through bridge is less than the height of the loads they carry.[26] These trusses are connected, then, by the bracing and deck stringers which also support the floor.

The floor system consists of beams connected from the intermediate posts to the opposite members, and thus are called floor beams. In highway bridges, such as the subject bridge, there are small beams parallel to the trusses and resting at their ends upon the floor-beams, and thus are called floor-joists.[27]

A truss is lighter than a girder of equal size; on the other hand, a truss is composed of many members, each of which is chosen for its particular role in a carefully thought-out play of stress versus strain. Thus, the truss will sag in the middle under a heavy load. But the upper chord (horizontal beam) of a truss is designed to meet a compressive strain, the lower chord to overcome a stretching, or "tensile," strain; and both vertical and diagonal units are laid out to pick up, convert, and transfer strains to places where they can be easily handled and for which the opposing force can be compensated.[28]

Bridge Plan History and Description -

The Penobscot River Bridge, known locally as the Bangor-Brewer Bridge, was erected in three distinct phases, beginning in 1902. The center truss (hereafter Span #1) consisted of a Baltimore (Petit) through truss, and while there are no drawings for this truss currently available, accurate newspaper accounts noted above place the date of construction by the American Bridge Company of Chicago Illinois as 1902. In 1911, Spans #2 & #3, located at either end and north and south of the central span, were added by the Boston Bridge Works, Boston Massachusetts as per construction drawings and the nameplate on the northern side of Span #3. In 1913, three Pony type trusses were added to the Bangor end of the bridge.

The center span was erected to be 217'-11" end to end ("out to out"); Span #2 (Brewer side) was erected to be 222'-10" out-to-out; Span #3 (Bangor side) was erected to be 217'-0" out-to-out. The center span was built to be 31'-11-1/2" wide, with a clear roadway width of 28'-11". Spans #2 & #3 were built to match.

The end of each span rested on either masonry or stone piers. Pier #1 was constructed of granite block, and provided a bearing surface of 9'-3", tapering out some 12' at the base. The height of the exposed portion of the pier was approximately 20' above mean high water. The pier measured 64'-0" long, two thirds of which was off-center to prevent downstream scouring.

Pier #2, constructed in a similar fashion, provided a bearing surface approximately 9'-5" wide, tapering out to 18'-0" at the base. The height of the exposed portion of the pier was 64'-0", situated as above to prevent scour. The pier consisted of coursed, ashlar rubble.

Pier #3, constructed as above, was completely reconstructed in 1969 by the MDOT. Since the original drawings for the 1911 spans show all three piers to be the same size, it is assumed that the actual sizing of this pier resembles the others, and that the construction of the piers was the domain of the constructions engineer.

Typically, the piers were established first, here consisting of stone laid in a random ashlar bond. Divers would first be sent down to survey the bottom, and help establish the outer boundaries of the piers. Piles would be driven in, using a steam-operated pile driver resting on a scow anchored in the river. Despite the river's earlier reputation, once the spring snow-melt runoff had occurred, the river quieted down rather quickly. At the same time, the falsework was constructed, typically using heavy timbers 8" square or bigger. This was to be the form on which the steel trusses would be erected.

One of the improvements that steel truss bridges offered was that parts could be created at a distant factory, the parts shipped to the site, and partially erected just off-site. This meant that the moment the falsework and cribbing support was completed, major portions of the bridge could be slid into place and erected, thus saving months of labor.

The present structure consists of three steel though truss spans and five rolled stringer deck spans. The trusses are subdivided Pratt trusses with counter having span lengths of: Span #1 - 222'-10"; Span #2 - 217'-11"; and Span #3 - 217'-0". The trusses of each span are 31'-11-1/2" wide center to center, providing for a roadway width of 28'-7" curb to curb. The depth of the trusses is 36'-0" from the center of the top chord to the center of the bottom chord.[29] All rivets are 3/4" thick, with 1" heads.

The floor system consists of transverse floor beams at the panel points, approximately 15'-6" on center; longitudinal stringers with a variable spacing of between 8'-7" and 10'-3"; and transverse support beams for the deck at 3'-11" center to center. The deck consists of a 3" deep concrete-filled steel grating with a bituminous wearing surface varying from 2-1/2" thickness at the center of the roadway to 2" at the curbs. Spans #2 & #3 have a 5" steel open grating, 3'-2" wide along the west curb. There is a bracket-supported sidewalk west of the west truss with a distance from the face of the west curb to the outside edge of the sidewalk of approximately 10'-9".[30]

Bridge Reconstruction -

In 1934, Pony Truss Span #1 was removed, and replaced by a girder span. The falsework was first placed to both support the posy truss and the weight of the roadway. The photograph in this report shows that once support girders were tied into place, the truss could be removed, in this instance to create a more efficient turning lane onto the bridge from Bangor. Note the existing set of trolley tracks on both the bridge proper, and in the area of the new work.

In 1935, expansion plates were replaced, having rusted out. In 1938 new deck stringers were placed to support Span #3. From 1943-48, a series of repairs and modifications occurred, primarily to the deck surface. Given the relative shortages during WWII, the wood plank flooring was removed, and replaced with a concrete base and bituminous paving and new floor grating. The concrete base consisted of 3" of steel (together with 3/4" reinforcing rod) and concrete, while the paving consisted of bituminous concrete, a mixture of various hydrocarbons and concrete. In 1953, the flooring of the two remaining Pony Trusses was removed, and replaced by the combination flooring described above.

In 1963, the remaining two Pony Trusses were removed. MDOT documents explain that the girder span was erected in place, above the existing railroad tracks to minimize disruption. The steel girder framework was erected above the falsework, and a concrete base surface poured. The trusses were then removed (dismantled), and the girder span literally slid into place. Complete tie-in work was performed, and a bituminous roadway surface poured to match the existing surfaces.

Also in 1963, the piers were repaired or jacketed as needed. Pier #1 was originally constructed of granite block, with a reinforced concrete collar (added in 1969) approximately 3'-3" thick extending 19'-6" below the bearings to ground level. Concrete splash pads were placed across the top of the pier between the bearings.[31]

Pier #2 was originally constructed in a similar manner, and had minor masonry repairs. It too had a concrete collar added to the base. Pier #3 had been completely "rehabilitated" such that is appears to be a new reinforced concrete pier. This was performed in 1969 by MDOT personnel, who enclosed the pier in reinforced concrete, as well as driving in sheet steel pilings around the base. In 1976, additional bridge deck reflooring work was performed.

Present Condition -

The Penobscot Bridge's load rating has been lowered to 3 tons, passengers vehicles only. There is a significant amount of rust on all members, and obvious signs of metal, and hence, structural, fatigue. Despite recent repair work, the greatest amount of deterioration has historically taken place at the end of the floor beams, the ends of the floor supports, and the truss members at and below deck level. This may have been due to the structure's inability to shed water past these points, hence the deterioration.

The sway bracing is in good condition, as are the truss members above deck level. With a moderate amount of pitting, the truss members of Spans #1 and #3 are generally in fair to good condition, whereas those of Span #2 are in fair to poor condition. Specifically, the vertical chords are generally in good condition, with some surface pitting and peeling. The gussets are in good condition, again with surface pitting and peeling.

As evidenced by recent MDOT inspection reports, the majority of the wear, and hence the need for complete removal of the bridge, is in the structural condition of the major components. The greatest weakness of members in compression or tension is that ultimately, these forces weaken the steel's ability to remain moderately elastic. The diagonal tension members were perhaps those hardest affected, as several were bent from compression fatigue. In addition, many of the connections have signs of severe rust and corrosion, along with pitting and surface pitting.

LIST OF ALTERATIONS/ADDITIONS[1]

1902	Span #1 (center span) erected by American Bridge Co., Chioago, ILL.
1911	Spans #2 & #3 (northern and southern spans) erected by Boston Bridge Works, Boston, MA. Trolley lane added.
1913	Three Pony Trusses erected, Floor stringers replaced, manufactured by the Groton Bridge Company, Groton, CT.
1934	Pony Truss Span #1 (northernmost span) removed, and girder spans added over Maine Central Railroad tracks on Brewer side
1935	Expansion Plates replaced
1938	New stringers for 217' span
1943-45	Wood plank flooring removed, replaced with concrete and bituminous paving
1946	Bracket and Post reinforcement
1947	Girder span #6 refloored
1948	Railing replaced
1953	Pony span flooring removed, replaced with concrete and bituminous paving
1963	Pony Truss Spans # 2 & #3 removed, replaced with steel girder spans over Maine Central Railroad tracks
1969	Concrete jackets, metal sheeting and jackets, backwall armoring of truss piers
1976	Bridge deck reflooring

ENDNOTES

1. Thompson, Deborah. Bangor, Maine 1769-1914: An Architectural History. Orono, ME: University of Maine Press, 1988; p. 203.

2. Ibid.

3. Bangor Daily News. "Another Step to Free Bridge." Bangor, ME: Bangor Daily News Publishing Co., April 15, 1902, p. 2.

4. Ibid, p. 10.

5. Ibid.

6. Tyrrell, Henry G. History of Bridge Engineering. Chicago, IL: Published by the author, 1911; pp. 121-22.

7. Dufour, Frank O. and C. Paul Shantz. Bridge Engineering. Chicago, IL: American Technical Society, 1933; p. 2.

8. Ibid, p. 4.

9. Tyrrell, op. cit., p. 165.

10. Ibid, p. 142.

11. Ibid, p. 65.

12. Ibid, pp. 65-6.

13. Ibid.

14. Ibid, p. 66.

15. Hopkins, H. J. A Span of Bridges. New York, N.Y.: Praeger Publishers, 1970; p. 132.

16. Tyrrell, pp. 66-7.

17. Ibid, pp. 67-8.

18. Ibid. For a greater in-depth discussion of the design and engineering principles behind the calculation of stressed and live and dead loads, see Dufour and Shantz, pp 64-72.

19. Ibid, p. 171.

20. Hopkins, op. cit., p. 125.

21. Ibid, p. 126.

22. Ibid.

23. Ibid.

24. Ibid, p. 5.

25. Ibid, pp. 5-6.

26. Ibid, p. 4.

27. Ibid, p. 6.

28. Marshall, David. Model Railway Engineering. New York, NY: Harper & Brothers Publishers, 1942; p. 64-5.

29. Fay, Spoffard & Thorndike. Supplement to Bangor-Brewer Bridge Location and Feasibility Study - Technical Appendices. Boston, MA: November, 1974; p. A-65.

30. Ibid, pp. A-65-6.

31. Ibid, p. A-73.

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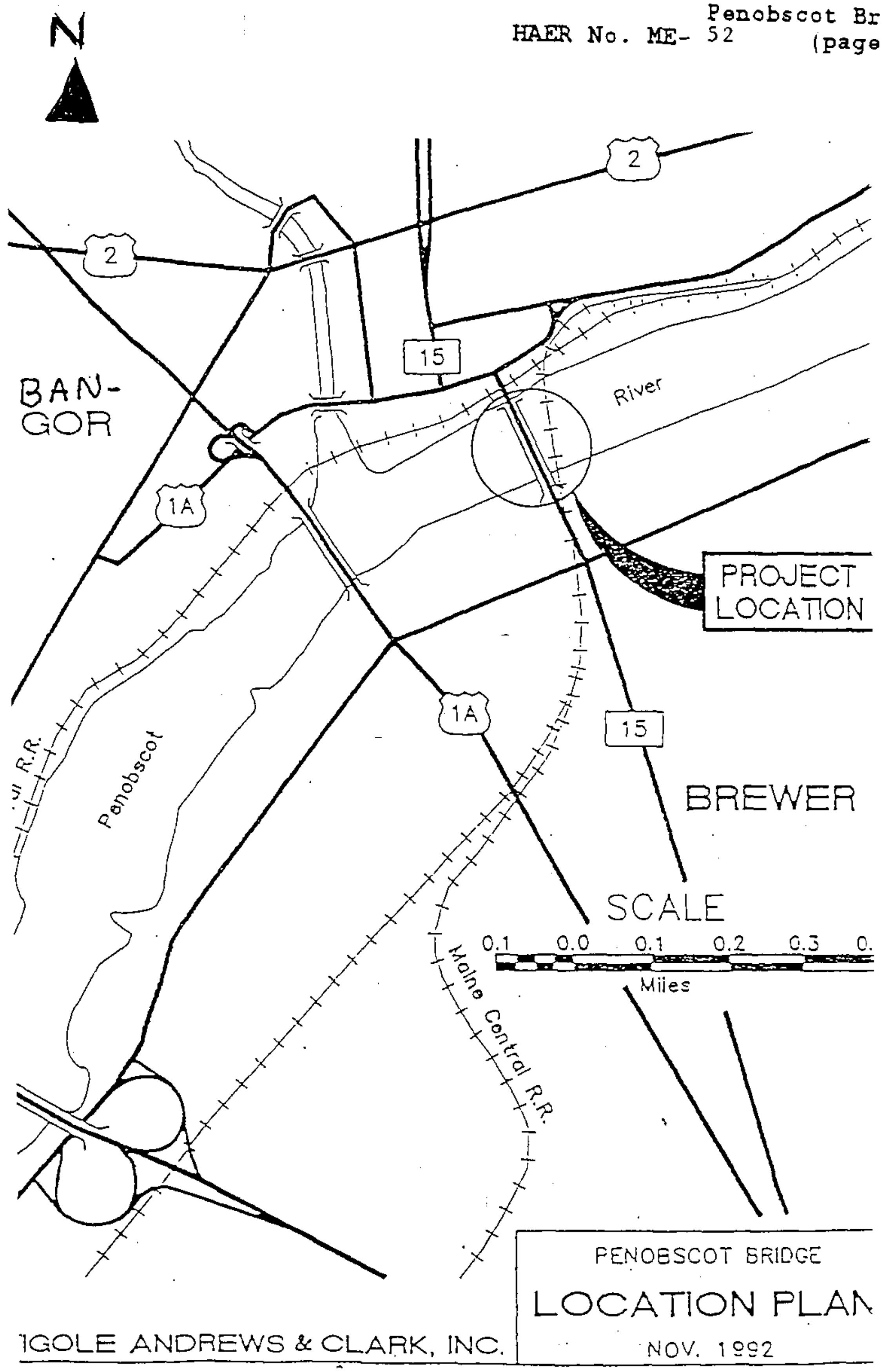
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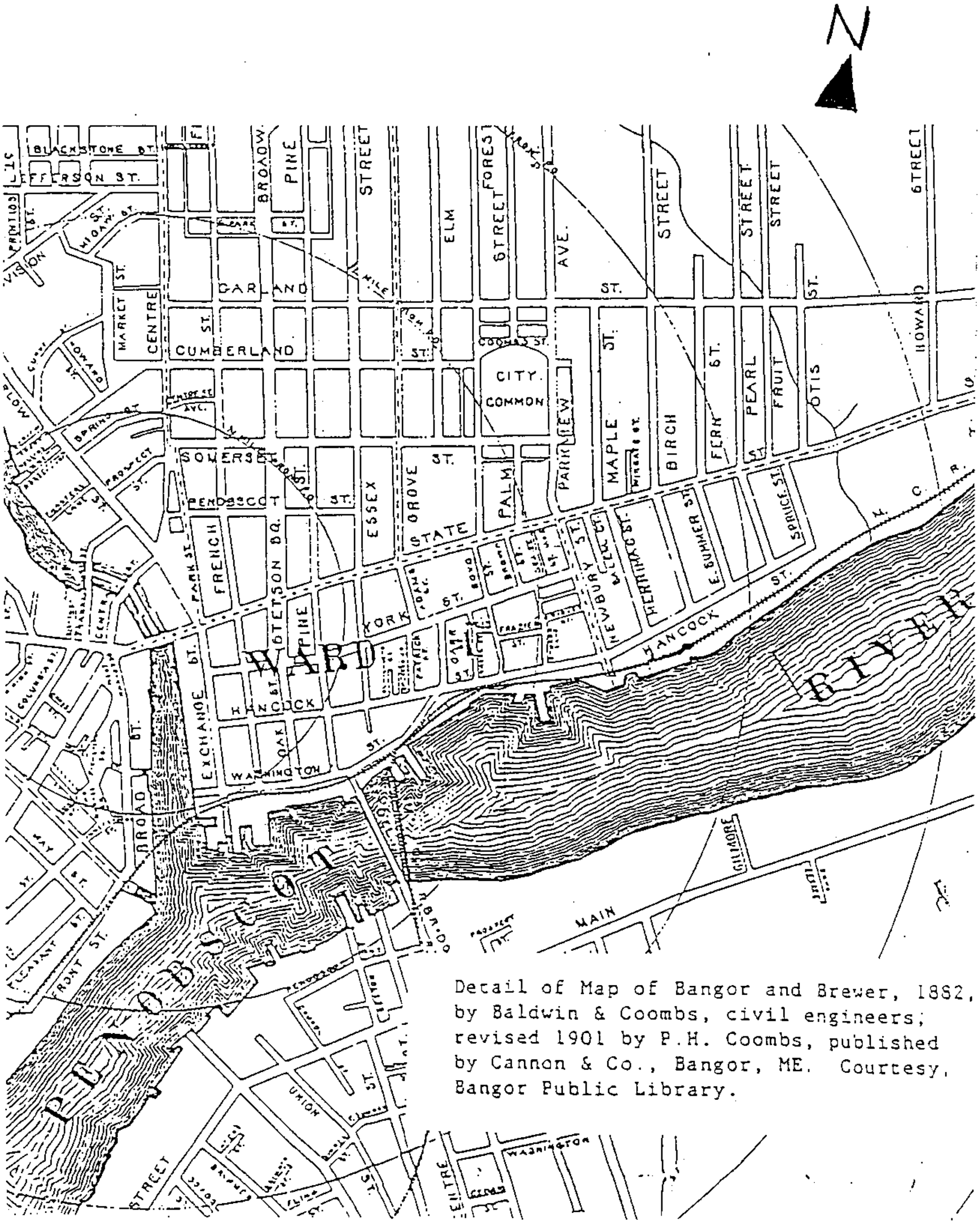

Detail of Map of Bangor and Brewer, 1882, by Baldwin & Coombs, civil engineers; revised 1901 by P.H. Coombs, published by Cannon & Co., Bangor, ME. Courtesy, Bangor Public Library.